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SFCW Generator Alignment Techniques

by

A. C. Phillips

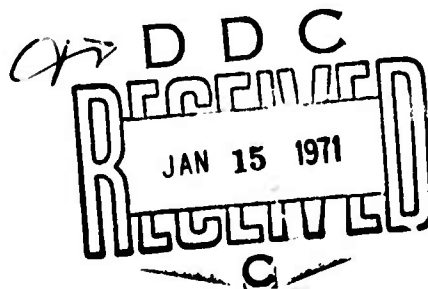
P. Evans

October 1970

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Technical Report No. 163

Prepared under
Office of Naval Research Contract
Nonr-225(64), NR 088 019, and
Advanced Research Projects Agency
ARPA Order No. 196



RADIOSCIENCE LABORATORY
STANFORD ELECTRONICS LABORATORIES
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SFCW GENERATOR ALIGNMENT TECHNIQUES

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Radioscience Laboratory
Stanford Electronics Laboratories
Stanford University Stanford, California

ABSTRACT

Depending on the design, synthesized-sweep SFCW generators often have phase discontinuities at certain intervals (such as 1 MHz) when sweeping over a wider band. In addition, when sweeping repetitively over a small interval (such as 100 kHz), the starting phase may not be coherent from one sweep to the next. Undesired phase discontinuities give rise to spurious spectral components and prevent application of MTI techniques. This report discusses modifications and adjustments for minimizing or avoiding phase discontinuities in SFCW exciters of the type first developed at Stanford University. The same approaches should be useful for other exciter designs as well. In addition, a novel oscilloscope display of wide applicability is described, which greatly simplifies both the measurement of phase coherence and the performance of corrective adjustments.

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1. INTRODUCTION

Continuing ionosphere research has required a continued increase in the sophistication of the signal processing of the sounder received signal. The more advanced signal processing techniques have in turn placed new requirements on the accuracy of the sounding signal generator. For the swept frequency CW (SFCW) case, accuracy infers phase predictability and continuity.

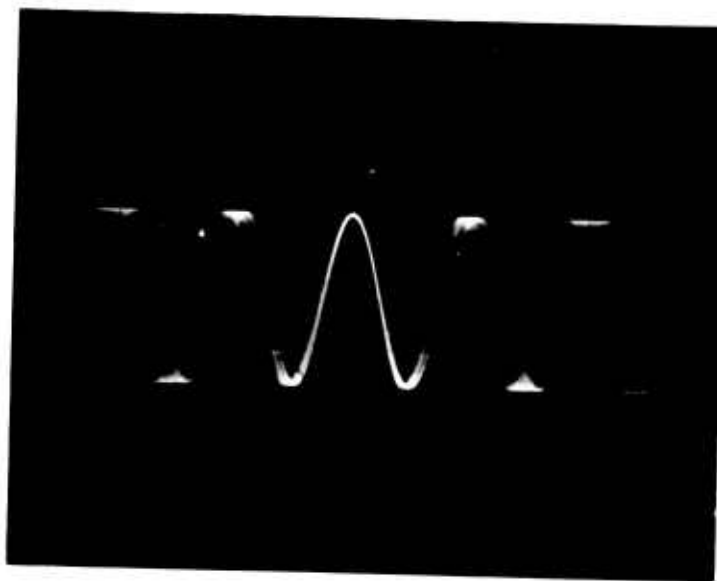
The Stanford-developed SFCW generators are often called "chirp" generators. The purpose of this report is to describe the necessary modifications to the Chirp III generators to enable their use in sounding systems where the phase of the SFCW signal must be accurately predictable at all times.

Phase continuity is generally provided by careful alignment and by compensation for circuit time delays. Some applications require that the signal phase be predictable over repeating sawtooth sweeps. It has been found that good phase continuity during the sweep does not ensure this required sweep-to-sweep coherence. Lack of coherence is caused by one of two things: either the flyback timing is incorrect, or the frequency dividers in the synthesizing process are unable to work properly due to the switching transients. This report describes techniques that were used to solve the above problems and thereby enable the more sophisticated signal processing to be performed on the SFCW receiver signal.

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II. A TECHNIQUE FOR OBSERVING THE PHASE CONTINUITY OF AN SFCW GENERATOR

A new technique for observing the phase continuity of an SFCW generator becomes possible when sweep-to-sweep coherence has been achieved. This technique makes use of the fact that a precise linear sweep can be sampled at a uniform rate in a manner resulting in the same phase at each sample. An oscilloscope display of this constant phase is obtained by triggering the oscilloscope externally at an appropriate rate and varying the display delay until the constant phase point is found (Fig. 1). This point of constant phase which can be observed on an oscilloscope will hereafter be called a phase coherent point.



Vertical: 1 V/Division
Horizontal: 500 ns/Division
Sweep Rate of SFCW Generator: 10 MHz/sec
Sweep Limits: 0.9 to 1.1 MHz
Trigger Rate: 1 kHz

Fig. 1. DISPLAY OF A PHASE COHERENT POINT.

The sampling rate to observe a phase coherent point can be found by finding the time required for the changing frequency to change the phase of the signal an integral number of cycles over what the phase would be had the frequency stayed constant. This fact is illustrated by the plot of frequency versus time of an SFCW signal as shown in Fig. 2. The area under a frequency-versus-time curve is proportional to the phase angle excursion of the phasor representing the signal. The numbers written

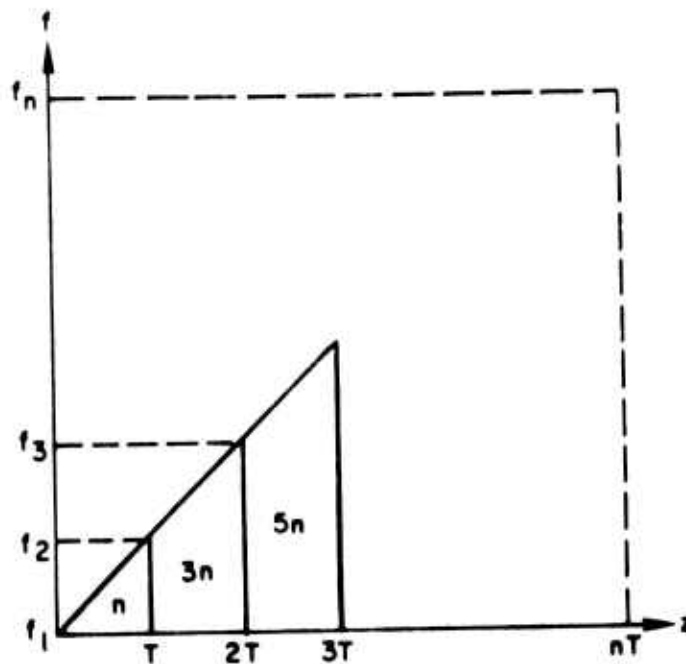


Fig. 2. SFCW PHASE REPRESENTATION.

into the blocked areas under the curve in Fig. 2 give the magnitude of the phase excursion during the time interval of T . The time, T , to complete n cycles is given by

$$T = \sqrt{\frac{2n}{S}} \quad (2.1)$$

where S equals the SFCW sweep rate in Hz/sec.

Figure 1 was made by triggering an oscilloscope at intervals found from Eq. (2.1). The time at the phase coherent point is such that the frequency (f_1, f_2, \dots or f_n in Fig. 2) times the sampling period equals an integer number of cycles. For the minimum sample period [$n = 1$ in Eq. (2.1)], the phase of the sampling to observe the phase coherent point is single valued.

The sampling time found from Eq. (2.1) is generally useful only when T is an integer. This is because it would be difficult to generate a trigger pulse chain having irrational time spacing between pulses. In addition, to observe the phase coherent point from sweep to sweep requires an integral number of sample intervals between the frequency limits. It would not be possible to find frequency limits which would result in a sweep time of an integral number of sample

periods when the sample period is irrational. The sample period normally used therefore is the smallest integer value of T . As an example, the smallest integer T for a sweep rate of 10^7 Hz/sec is found to be 10^{-3} sec by letting $n = 5$.

In the remainder of this report when reference is made to a phase coherent point it can be assumed that this means that the constant phase is observed by triggering an oscilloscope at a rate determined by the minimum integer value of T from Eq. (2.1).

If the trigger rate to observe a phase coherent point is not determined by letting $n = 1$ in Eq. (2.1), the phase of the trigger pulse train is not single valued. In the above example of a 10^7 Hz/sec sweep rate giving a 10^{-3} sec trigger period to observe a phase coherent point, there are ten phases of the trigger pulse train that will give a phase coherent point at the same position on the oscilloscope. These differing phase coherent points have differing phases, thus preventing triggering at a higher rate and observing all ten of the phase coherent points at the same time.

To check for phase discontinuities it is generally most convenient to have the SFCW generator in a continuous sawtooth sweep mode with the limits and sweep rate set such that the phase coherent point observed on the oscilloscope remains the same phase sweep to sweep. If one had an ideal linear sweep it would suffice to have each frequency limit be a frequency that could be observed at a particular phase coherent point. The digitally controlled synthesizer, however, is not in general capable of an ideal approximation to a linear sweep. Figure 3a shows the ideal step approximation to a linear sweep while Fig. 3b illustrates the fact that the digitally controlled synthesizer flies back to the start frequency (f_L in this case) immediately upon reaching the limit (f_H in this case). For some sweep rates it would be possible to design the digitally controlled synthesizer to flyback phase coherently at the ideal time. For other sweep rates, however, the basic synthesizing frequencies are not in phase at the ideal flyback time, making it impossible to flyback phase coherently at the ideal flyback time. The resulting phase error θ_e between the ideal step approximate to a linear sweep and the

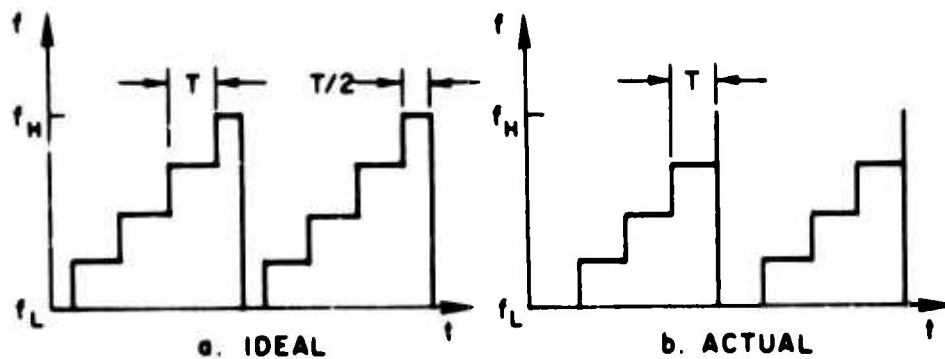


Fig. 3. STEP APPROXIMATION TO A LINEAR SWEEP.

operation of the digitally controlled synthesizer is (assuming operation as illustrated by Fig. 3b)

$$\theta_e = (f_H - f_L) \frac{\Delta t}{2} \quad (2.2)$$

where Δt is equal to the time interval of one frequency step. There are two ways to use Eq. (2.2). First f_H and f_L can be selected to make the error θ_e equal to 1 cycle. If f_H and f_L are frequencies at a phase coherent point the 1 cycle error will result in succeeding sweeps which are phase identical. A second way to use Eq. (2.2) is that, given f_H and f_L , one can find θ_e and calculate how many sweeps are required to accumulate an error of 1 cycle.

The ability to observe a phase coherent point by appropriate oscilloscope triggering greatly simplifies many adjustments that must be made to achieve phase continuity in an SFCW generator. Heretofore, such adjustments were made by mixing two SFCW generators together and observing the phase discontinuities in their difference frequency. The two-SFCW generator method results in a cumbersome test setup.

The oscilloscope triggering pulse train required for the phase coherent display is easily obtained from the SFCW frequency reference by a chain of frequency dividers. In addition to providing the triggering pulse train, the divider chain is continued to give a 1 pulse per second (pps) output. The 1 pps signal is used to initiate the SFCW sweep to

result in a known relation between the phase of pulse train and the beginning of the SFCW sweep. This feature eliminates the difficulty of finding the phase coherent point when the sweep has been stopped or when the frequency limits have been changed. A block diagram of the triggering system is shown in Fig. 4.

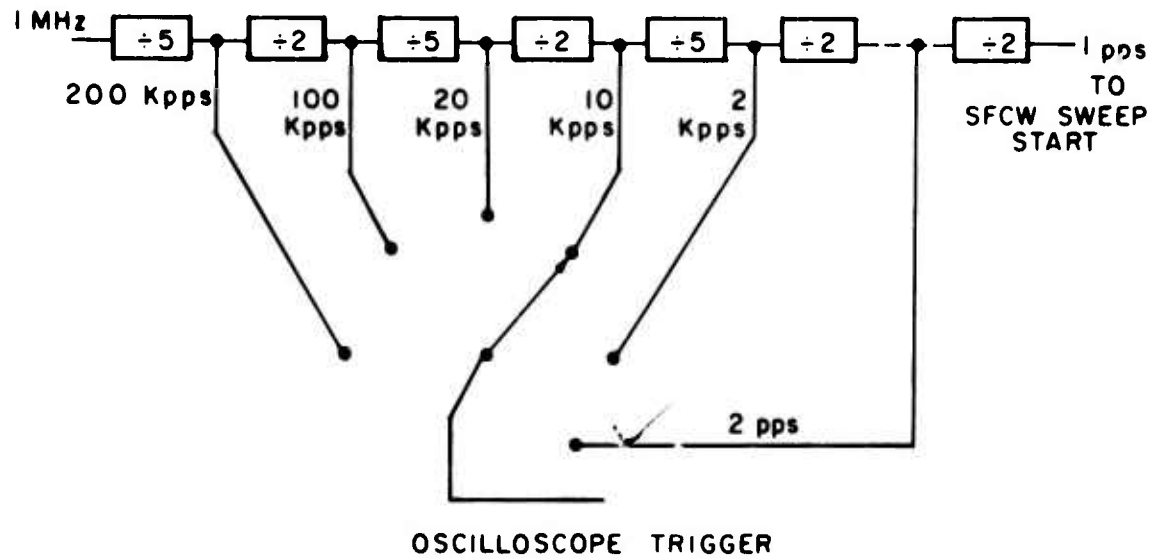


Fig. 4. TRIGGERING SYSTEM.

III. BASIC SYNTHESIZER OPERATION

The basic operation of the Hewlett-Packard Synthesizer involves a series of mixing and dividing selected frequencies to arrive at a precise frequency.

The operation of an arbitrary decade in the HF section of the synthesizer can be described as follows: Referring to Fig. 5, a 27.0 MHz to 27.099 ... MHz signal is mixed with a 3.0 to 3.9 MHz signal selected from the switching matrix. The 100 kHz digit in the 3.0 to 3.9 MHz signal represents which frequency digit in that column was selected. Thus 3.5 MHz represents a 5 selected in that column. The resultant signal out of the mixer is 30.00 ... to 30.999 ... MHz, again with the 100 kHz digit representing the selected signal from the decade of interest. The 30.00 ... to 30.999 ... MHz signal is then filtered to remove the lower order mixed signal at about 24 MHz. Then, the 30.00 ... to 30.999 ... MHz signal is divided by 10 to give a 3.00 ... to 3.099 ... MHz signal. Here the 10 kHz digit represents the selected frequency digit of the decade of interest.

The 3.0 to 3.099 ... MHz signal is then mixed with a 24 MHz signal and filtered to give a 27.000 ... to 27.0999 MHz signal. This signal is then sent to the next decade where it is mixed with a 3.0 to 3.9 MHz signal selected from the switching matrix. The process continues until all decades, from the 0.01 Hz decade to the 100 kHz decade, have processed signals out of the switching matrix. The output, at 30.00 to 30.99 ... MHz (not 3.0000 to 3.0999--because the 100 kHz decade does not include a divider), then goes to the VHF portion of the synthesizer. Further explanation of the Hewlett-Packard Synthesizer operation can be found in the operating and service manual.

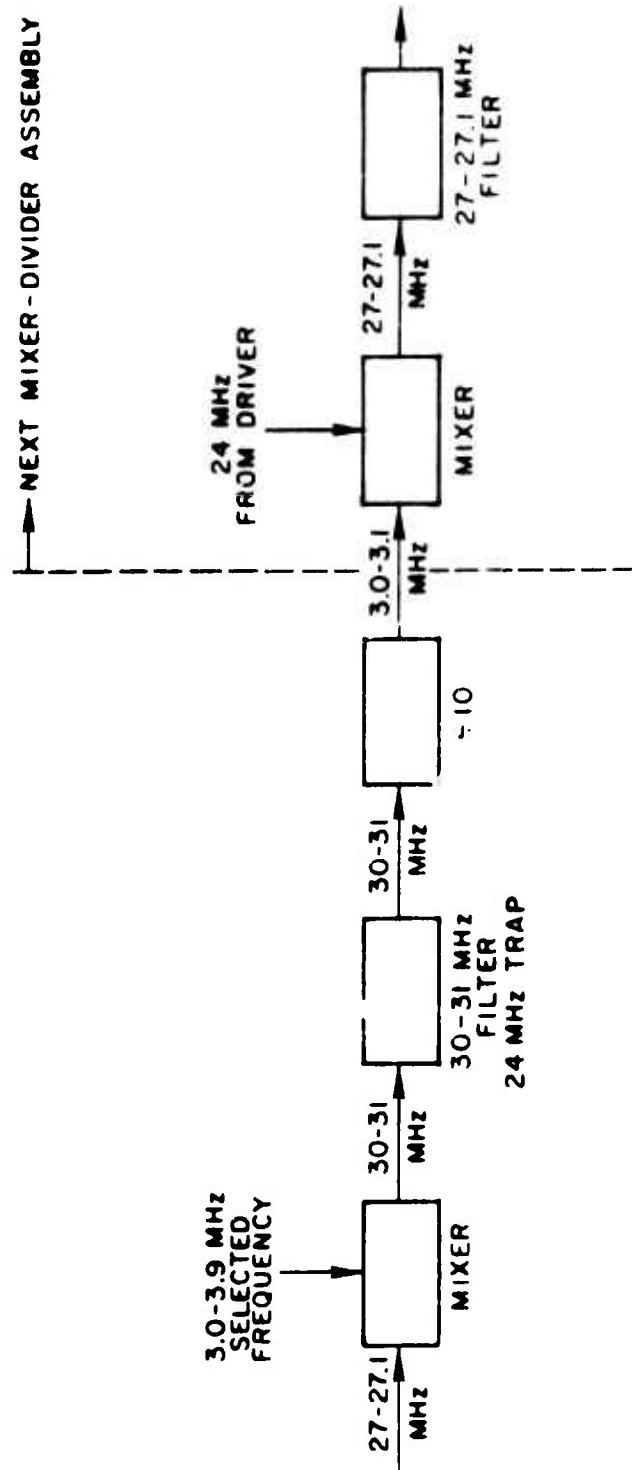


Fig. 5. BLOCK DIAGRAM FOR A DECADE ON THE HEWLETT-PACKARD FREQUENCY SYNTHESIZER.

IV. COHERENT SFCW OPERATION

For an SFCW generator to be coherent requires that the phase of the output signal be predictable at all times. Examining the block diagram of a decade (Fig. 5) of the synthesizer used in Chirp IIIs, it is noted that most operations are that of algebraic addition of frequencies and filtering. A loss of signal for these operations would only result in an amplitude transient at the output while the phase reference remains constant. However, the operation of the divide by 10 circuit has a critical relationship with respect to the phase of the output signal. If the frequency divider were to lose count as a result of a transient at the input of the divider, the output signal's phase would be incorrect and the SFCW generator would be incoherent. The divider works most reliably with an input that is constant in amplitude and as free as possible of transients at the frequency switching points. This requires that the 30 to 31 MHz filter which precedes the divider be adjusted to minimize transients at the switching points. The divider should be adjusted to divide properly for the range of input frequencies.

The only decades in the Chirp IIIs that use frequency dividers are the 0.01 Hz to 10 kHz decades. For the 100 kHz and higher decades, all operations are addition and subtraction, and thus these decades do not lose their phase reference due to a transient or loss of signal.

The study of SFCW generator coherence can be separated into two cases--one case with the generator sweeping continuously, the other with the generator making a large transition in frequency such as a flyback transition at the end of a sweep.

The continuous case is defined as a linear stepping in frequency with an increase or decrease in frequency. To the mixer-divider decades this linear stepping corresponds to 100 kHz transitions in the 3.0 to 3.9 MHz signal into the mixer-divider decade and a linear stepping of the 27.0 to 27.099 ... MHz signal. While linear stepping in frequency, the largest transition in frequency is a change of 100 kHz which occurs in the signal going to the 30 to 31 MHz filter. Since it is desirable to maintain a relatively constant amplitude out of this filter which is

followed by a divide by 10 frequency divider, the 30 to 31 MHz filter's phase and dispersion must be adjusted to maintain an output that is as constant as possible during the 100 kHz frequency transition.

The mixer-divider decades cannot run continuously because each decade must reset from a 9 to a 0 if sweeping up or a 0 to a 9 if sweeping down. This corresponds to a change in the selected 3.0 to 3.9 MHz signal of 3.9 MHz to 3.0 MHz or 3.0 MHz to 3.9 MHz. Here, the worst case transition, which may be considered a flyback transition, is 900 kHz. This flyback transition occurs at a predictable rate in each decade and occurs most often in the lowest decades that are switched. As before, the 30 to 31 MHz filter must be adjusted to accommodate this transition with a minimum of amplitude variation at the output.

One other type of flyback transition in frequency occurs when the SFCW generator reaches an upper or lower limit and resets to a predetermined frequency. This transition involves frequency transitions of 0 to 900 kHz with 100 different combinations of frequency transitions as determined by the upper, lower, and start frequency control switches. Since the Chirp IIIs have frequency setting control switches only in the 1 kHz to 10 MHz decades, only these decades need to be considered for this type of flyback transition. As mentioned before, the 100 kHz and higher decades need not be considered for adjustment to ensure coherence.

Thus the 0.01 Hz decade through the 100 Hz decade must be adjusted to remain coherent for the continuous operation and the two cases of 3.9 to 3.0 MHz and 3.0 to 3.9 MHz flyback. The 1 kHz and 10 kHz decade must be adjusted to remain coherent for continuous operation and both the 3.9 to 3.0 MHz and 3.0 to 3.9 MHz flyback and the 100 different frequency flyback transitions.

In the Chirp IIIs, the 3.0 to 3.9 MHz signal in the 1 kHz decade comes directly from the switching matrix and, because of switching transients, the signal, after being mixed to 30 to 31 MHz, contains energy outside the 30 to 31 MHz filter passband. Adjustment of the 30 to 31 MHz filter is therefore more critical in this decade. In the 10 kHz decade, the 3.0 to 3.9 MHz signal from the switching matrix goes through an all-pass delay network and receives some filtering so that the signal resulting from the mixing of the 3.0 to 3.9 MHz signal and the 27.00 to

27.099 ... MHz signal from the previous decade contains a higher percentage of its energy within the 30 to 31 MHz filter. This greatly simplifies the alignment of the 30 to 31 MHz filter for the 10 kHz decade.

The 30 to 31 MHz filter in the 1 kHz decade was modified by changing the filter from four to two poles, decreasing the dispersion and making the phase response approximately linear. This was done both to reduce time delay of the signal in the filter and to facilitate the adjustments to achieve coherence.

A modification was also made to the gate drivers on the modulo 10 counter boards (see Fig. 6). If no gates were turned on, the voltage out of the switching matrix for the particular decade would rise to a large positive value relative to the signal level. If there was any delay in selecting a new frequency after another gate was turned off, a spike would occur on the switching matrix output. Since this spike contains energy outside the desired band of 3.0 MHz to 3.9 MHz, it is desirable to eliminate it. The method used was to delay a gate drive turn-off while maintaining a rapid turn-on time.

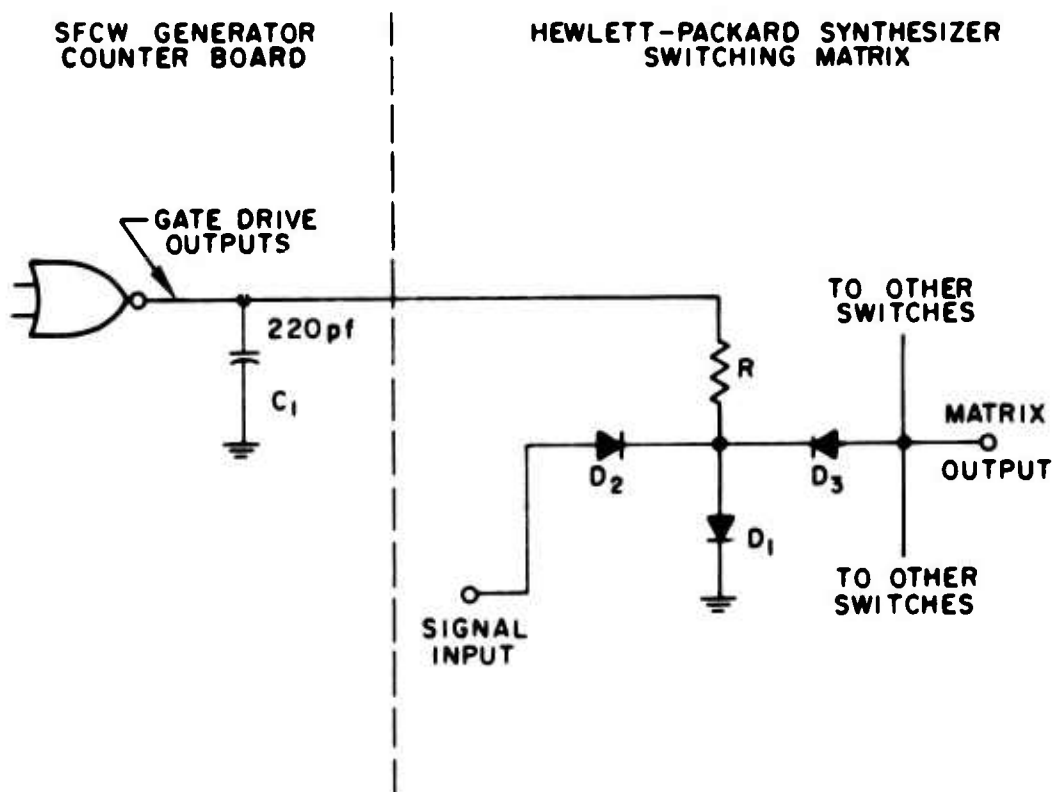


Fig. 6. MODIFICATIONS MADE TO THE GATE DRIVER OUTPUTS.
Capacitor C1 added.

The method used to observe flyback transients in the 30 to 31 MHz filters and dividers was to trigger the oscilloscope with the reset pulse out of the chirp and observe filter amplitude variations and divider coherence. This method is very useful because it triggers the oscilloscope at the flyback time regardless of the frequency limits. The use of the flyback transition for determining coherence is preferable to observing other parts of the waveform, as the divider will usually lose coherence when making a flyback transition before the dividers fail under any other conditions.

The 30.0 to 31.0 MHz filters were adjusted to give an amplitude as flat as possible when sweeping over the full range of the filter and minimize amplitude variations during flyback. The dividers following the filters were adjusted to minimize output transients and assure proper operation over the whole range of frequencies that the divider would encounter.

V. SIGNAL DELAY ADJUSTMENTS

The main reason for adding delays in the signal switching lines out of the switching matrix and removing delays from the mixer-divider modules was to compensate for delays through the synthesizer so that the frequency switching would appear to occur simultaneously as seen at the output. This would reduce frequency and phase errors as seen at the output and would reduce the sidelobe level of the chirp waveform caused by phase transients at the switching points.

For the decades below the 100 Hz decade, no effort was made to reduce phase transients. Even though these decades, when driven, are switched at a higher rate than are the higher decades, the resultant contribution to phase transients at the output is reduced because the phase errors are divided down by the following decades. Thus, their contributions to the sidelobe level of the output signal are minimal.

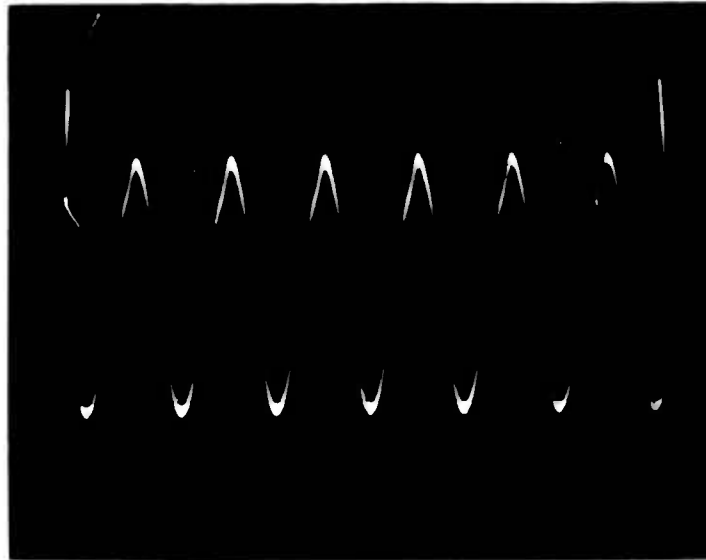
In the 100 Hz decade, however, the delay in the filter was reduced. The result is that when the 100 Hz decade and 1 kHz decade are switched, the signal that is mixed together in the 1 kHz decade to form the 30 to 31 MHz signal undergoes a more nearly simultaneous frequency transition that minimizes the frequency and phase error. The modifications that were made to achieve reduced delays were a reduction in the filtering of the 30 to 31 MHz filter in the 100 Hz decade and the 27 MHz filter in the 1 kHz decade.

For the 10 kHz and 100 kHz decades, all-pass delay networks were installed. These allowed adjustment of the delays in the switching matrix output signals to make the signal switching occur at more nearly the same time and thus reduce phase transients.

VI. SFCW PHASE ALIGNMENT

To minimize the phase transients when switching the various decades, the delays for each decade must be adjusted. For the 10 kHz and 100 kHz decades, this involves adjusting phase shifting networks at several different frequencies. The 1 MHz decade is adjusted by varying the phase of each individual frequency. It should also be mentioned that the phase alignment requires coherent operation by the SFCW generator both in the continuous and flyback conditions. Without coherent operation, no prediction could be made about the phase of the output of the synthesizer from sweep to sweep as well as during the sweep, and any attempt at phase alignment would be meaningless. Therefore, it is necessary that the generator be checked for coherent operation before attempting to adjust the delays for a minimum in phase transients.

The following procedure is followed to adjust the delay that is inserted in the matrix output going to the 10 kHz mixer divider. The oscilloscope vertical deflection is obtained from the output of the 30 to 31 MHz filter in the 10 kHz column. This signal rather than the synthesizer output is used to give greater phase sensitivity. The oscilloscope is triggered at a phase coherent rate by the triggering system described in Chapter II. In that case the sweep rate used to calculate the trigger rate from Eq. (2.1) is 10 times the SFCW generator setting. (This is because the signal is divided by 10 before being used in generating the synthesizer output.) The SFCW frequency limits are set to sweep over a 20 kHz range, with the 1 kHz and lower limits set at zero, with a further restriction that the sweep does not sweep across an even 100 kHz point. The phase coherent point is found by varying the oscilloscope delay. If the matrix delay line is properly adjusted, a single phase sine wave will be found at the phase coherent point, as shown in Fig. 7. Greater sensitivity in observing proper delay adjustment, however, is found by changing the oscilloscope delay to observe the waveform slightly before or after the phase coherent point. If the delay is properly adjusted, there will be a uniform spreading in phase of a group of sine waves. If the delay is not perfectly adjusted, there will be a splitting into two groups of sine waves. On one side of the phase coherent point the two groups will



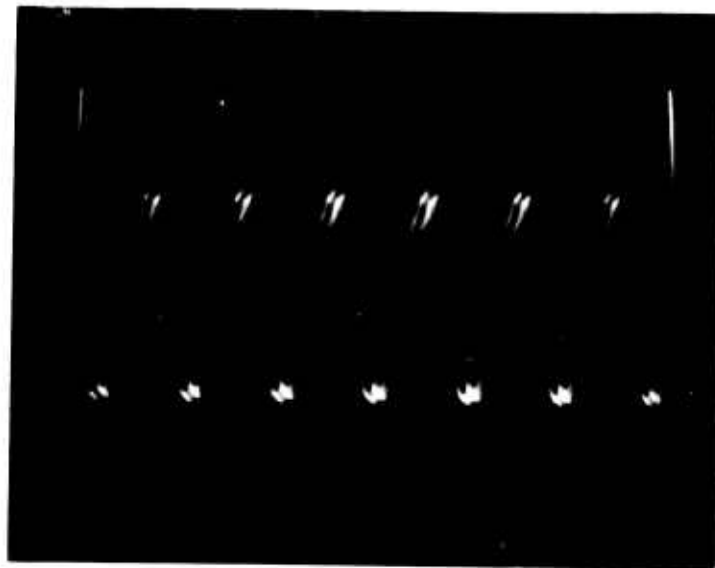
Horizontal: 20 ns/Division
Sweep Rate of SFCW Generator 1 MHz/sec

Fig. 7. PHASE COHERENT POINT OBSERVED AT THE 30 TO 31 MHz FILTER OUTPUT IN THE 10 kHz MIXER DIVIDER. The SFCW generator sweep rate is 10^6 Hz/sec.

overlap, while on the other side there will be a gap between the two groups, as shown in Fig. 8. When the delay has been adjusted such that the spreading in phase looks similar on each side of the phase coherent point, nearly perfect compensation has been achieved.

When the delay has been properly adjusted for a particular 20 kHz sweep range, it will be found that this value of delay is not exactly correct for other 20 kHz ranges because of the dispersion in the filters. Therefore, as a final adjustment, the phase errors at the phase coherent point are minimized while sweeping over the full 100 kHz. It should be remembered that any residual phase errors due to imprecise adjustments in the 10 kHz delay are divided by 10 before being used to synthesize the final SFCW output signal.

The 100 kHz decade delay is adjusted by observing the synthesizer output while the SFCW generator is swept over a 1 MHz range that does not include any 1 MHz transitions (except at the end of the range). As before, the oscilloscope is triggered at a phase coherent rate. The delay adjustments are made to minimize phase errors at the phase coherent



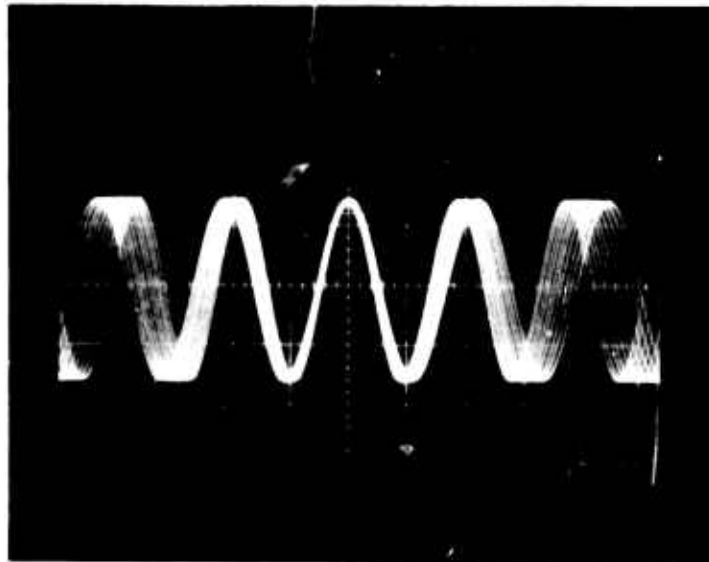
Horizontal: 20 ns/Division

Sweep Rate of SFCW Generator: 1 MHz/sec

Fig. 8. ESSENTIALLY THE SAME WAVEFORM AS IN FIG. 7 EXCEPT THAT THE OSCILLOSCOPE DELAY IS ADJUSTED TO OBSERVE THE WAVEFORM AT A TIME SLIGHTLY DEVIATED FROM THE PHASE COHERENT POINT.

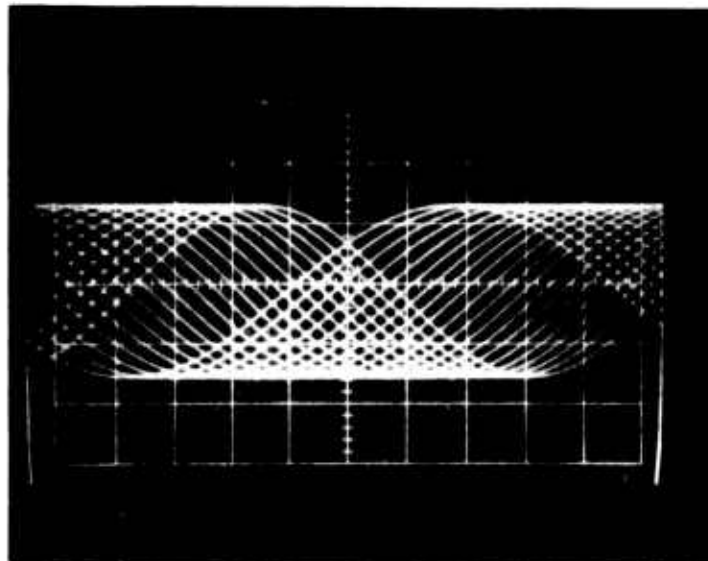
point. When properly adjusted, the phase coherent point would appear as in Fig. 9, and a short time before or after as in Fig. 10. The transition of 3.9 to 3.0 MHz (or 3.0 to 3.9 MHz) cannot be adjusted here but will be adjusted with the 1 MHz transition adjustments.

The adjustments in the 1 MHz decade is different from the previous method because of the availability of each switching frequency. Each MHz transition, from 0 to 1 MHz, 1 to 2 MHz, etc., can be adjusted individually. The SFCW generator is swept from 100 kHz below to 100 kHz above the MHz transition. These limits avoid having any 100 kHz transitions except 9 to 0 or 0 to 9 and thus eliminate any errors in the display coming from these transitions. The 200 kHz sweep range also allows the use of a 1 kHz trigger rate, thus displaying the synthesizer output every 10 kHz. The delay and phase of one of the signals from the synthesizer driver (30 to 39 MHz) is adjusted to bring the two groupings of signals together at the phase coherent point. The two groups arise from the fact that below the MHz transition, the phase transients have been minimized, and above the MHz transition the phase transients have been minimized except that the group is shifted by the phase transient of the MHz transition. The phase of the signal from the synthesizer driver is adjusted to bring these



Vertical: 1 V/Division
 Horizontal: 500 ns/Division
 Sweep Rate of SFCW Generator: 10 MHz/sec
 Sweep Limits: 0.9 - 1.1 MHz
 Trigger Rate: 500 Hz

Fig. 9. SFCW GENERATOR OPERATING AT 10 MHz/sec FROM 900 kHz TO 1.1 MHz AND SHOWING THE PHASE COHERENT POINT OF THE GENERATOR OUTPUT BEFORE AND AFTER A 1 MHz TRANSITION.

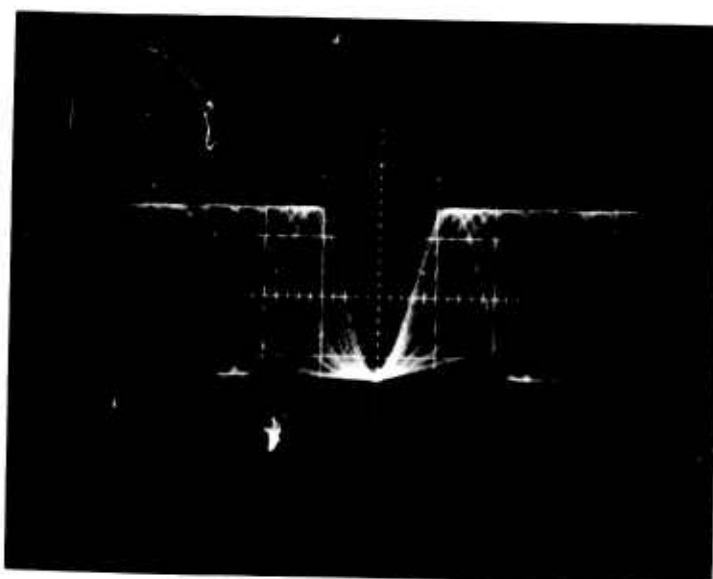


Vertical: 1 V/Division
 Horizontal: 100 ns/Division
 Sweep Rate of SFCW Generator: 10 MHz/sec
 Sweep Limits: 0.9 - 1.1 MHz
 Trigger Rate: 1 kHz

Fig. 10. SAME AS FIG. 9, EXCEPT THAT THE SCOPE DISPLAY HAS BEEN DELAYED 3.5 μ sec AFTER PHASE COHERENT POINT AND EXPANDED 5 TIMES TO SHOW 20 DIFFERENT PHASES (TRIGGER RATE DOUBLED).

two groups together. The synthesizer driver signal that is adjusted is usually the upper MHz signal and the transitions adjusted are 0 to 1 MHz, 1 to 2 MHz, etc. Care must be taken not to affect the phases of the 3.0 to 3.9 MHz signals out of the synthesizer driver or they will have to be readjusted. The proper phase alignment at and near the phase coherent point is shown in Fig. 11. As before, the 9 to 10 MHz transitions (which correspond to 39 to 30 MHz or 30 to 39 MHz transitions out of the 30 to 39 MHz switch) are not adjusted in this decade and must be compensated by some other means, such as adjusting the 350 to 390 MHz signals. A modification of the 30 to 39 MHz switch was made by Barry Research in order to reduce loading on the 30 to 39 MHz signals from the synthesizer driver. This is necessary to keep proper phase alignment and minimize phase errors when using different 10 MHz ranges.

The results obtained by mixing two SFCW generators together using a test setup shown in Fig. 12 are shown in Figs. 13a, 13b, and 13c. The phase discontinuities are less than 24° for transitions other than 10, 20, 30, etc. MHz transitions.



Vertical: 1.0 V/Division
 Horizontal: 50 ns/Division
 Sweep Rate of SFCW Generator: 10 MHz/sec
 Sweep Limits: 0.9 - 9.1 MHz
 Trigger Rate: 1 kHz

Fig. 11. SFCW GENERATOR OPERATING AT 10 MHz/sec FROM 900 kHz to 9.1 MHz AND SHOWING THE PHASE COHERENT POINT OF THE GENERATOR OUTPUT.

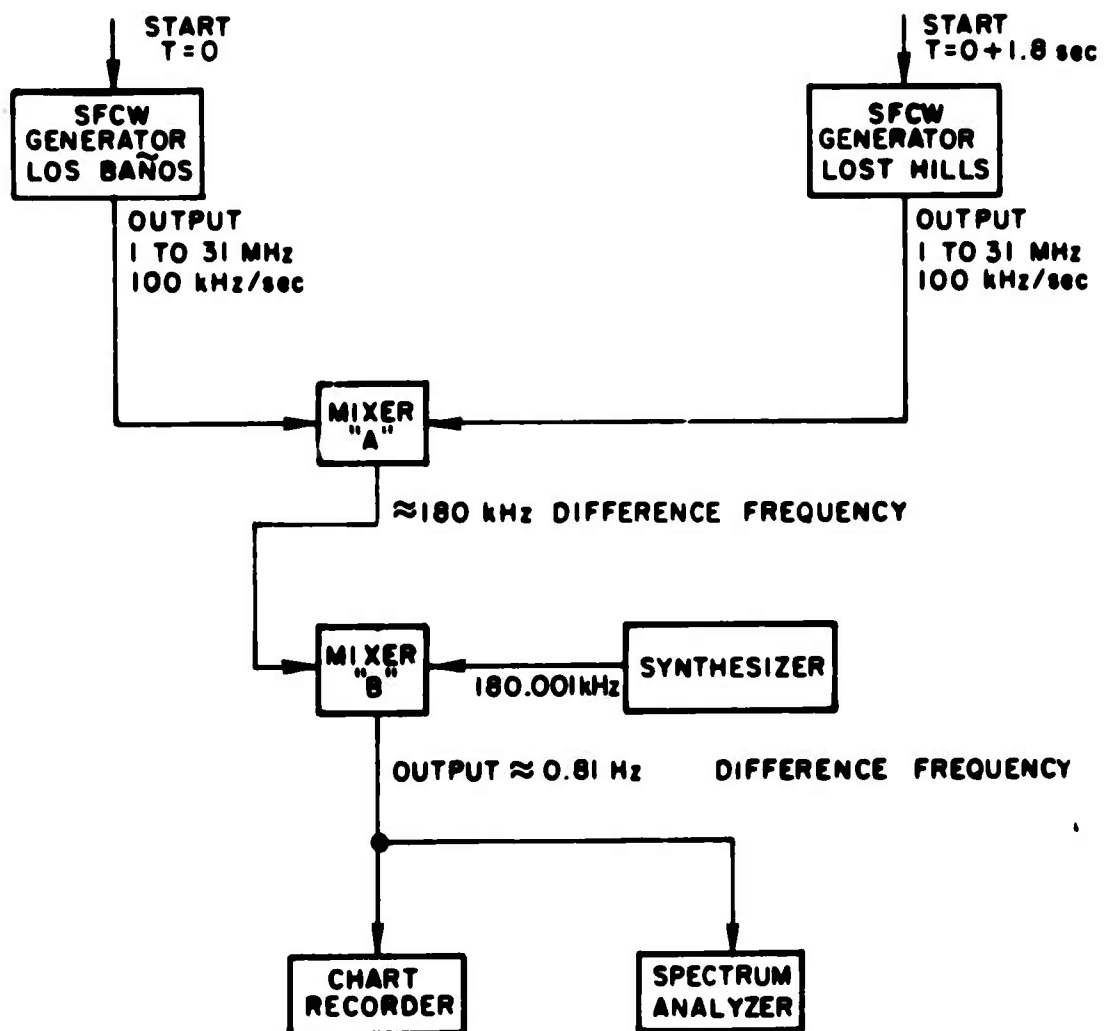
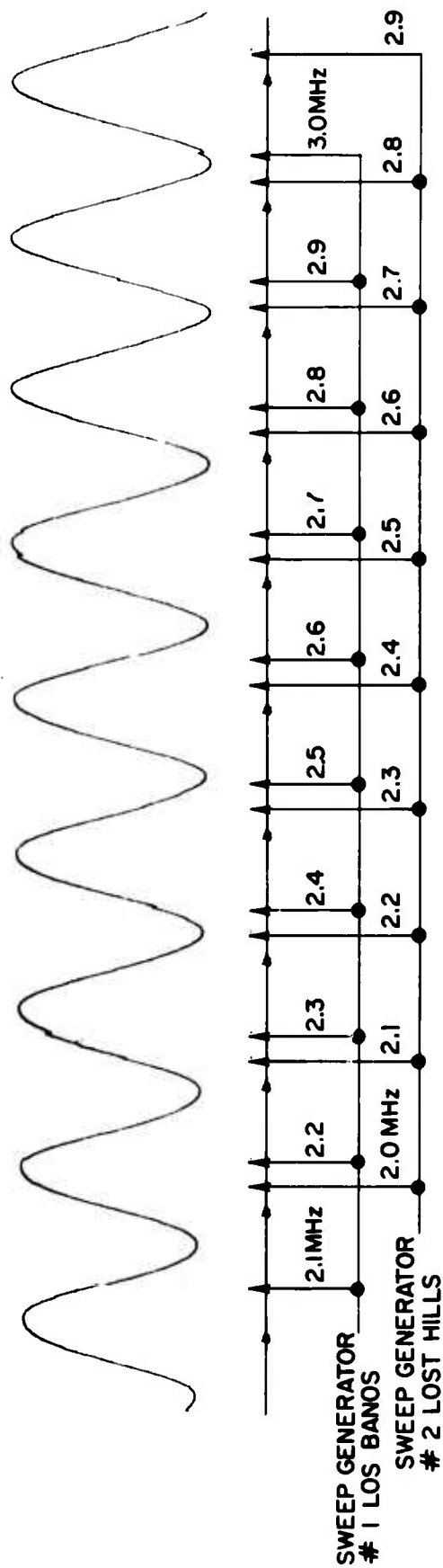
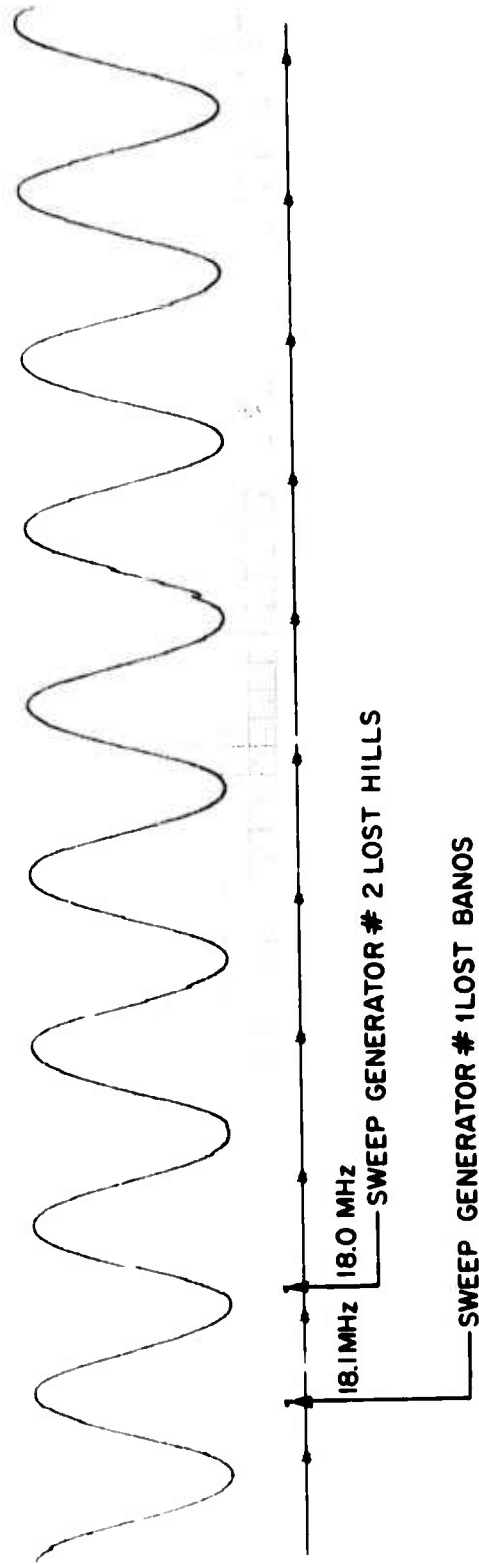


Fig. 12. TEST SETUP USED TO MEASURE THE PHASE DISCONTINUITIES IN SFCW GENERATORS.



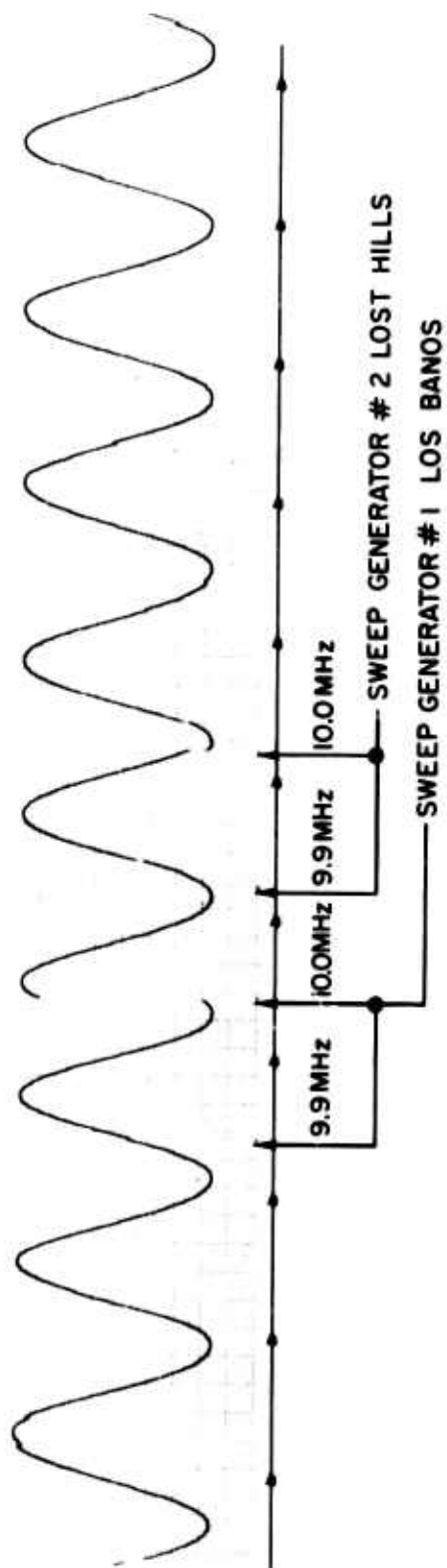
a. 0.81 Hz difference frequency from mixer B (Fig. 12) for a sweep from 2.0 MHz to 3.0 MHz.

Fig. 13. CHART RECORD OBTAINED FROM MIXING TWO CHIRP IIIs TOGETHER SHOWING PHASE TRANSIENTS OF LESS THAN 24° (EXCEPT FOR 10, 20, 30, ETC., MHz TRANSITIONS).



- b. 0.81 Hz difference frequency output from mixer B (Fig. 12) for an 18 MHz to 19 MHz sweep showing that the phase transients are similar to those found in a 2.0 MHz to 3.0 MHz sweep.

Fig. 13. CONTINUED.



c. Uncompensated 10 MHz frequency transition in both SFCW generators.

Fig. 13. CONTINUED.

VII. CONCLUSION

Coherent and phase continuous operation of a Stanford Chirp III SFCW generator was achieved by circuit modifications and adjustments. Phase predictability was achieved for conditions during the SFCW sweep and also after flyback in a sawtooth sweep mode. A method of oscilloscope triggering to observe the phase continuity of an SFCW signal was described and demonstrated (Fig. 11).

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13 ABSTRACT <p>Depending on the design, synthesized-sweep SFCW generators often have phase discontinuities at certain intervals (such as 1 MHz) when sweeping over a wider band. In addition, when sweeping repetitively over a small interval (such as 100 kHz), the starting phase may not be coherent from one sweep to the next. Undesired phase discontinuities give rise to spurious spectral components and prevent application of MTI techniques. This report discusses modifications and adjustments for minimizing or avoiding phase discontinuities in SFCW exciters of the type first developed at Stanford University. The same approaches should be useful for other exciter designs as well. In addition, a novel oscilloscope display of wide applicability is described, which greatly simplifies both the measurement of phase coherence and the performance of corrective adjustments.</p>		

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	ROLE	WT	ROLE	WT	ROLE	WT		
FREQUENCY SWEEP FREQUENCY SYNTHESIZER HIGH FREQUENCY PROPAGATION IONOSPHERIC SOUNDING PHASE ALIGNMENT PHASE COHERENCE PHASE COHERENT SAMPLING PHASE CONTINUOUS SWEEP SWEEP FREQUENCY C.W. (SFCW) SYNTHESIZED FREQUENCY SWEEP								